



**US Army Corps
of Engineers**
Hydrologic Engineering Center

Some History and Hydrology of the Panama Canal

Technical Paper No. 159

June 2000

20010601 076

Papers in this series have resulted from technical activities of the Hydrologic Engineering Center. Versions of some of these have been published in technical journals or in conference proceedings. The purpose of this series is to make the information available for use in the Center's training program and for distribution within the Corps of Engineers

The findings in this report are not to be construed as an official Department of the Army position unless so designated by other authorized documents.

The contents of this report are not to be used for advertising, publication, or promotional purposes. Citation of trade names does not constitute an official endorsement or approval of the use of such commercial products.

Some History and Hydrology of the Panama Canal

**Arthur F. Pabst
US Army, Corps of Engineers
Hydrologic Engineering Center
Davis, California**

Presented at
Watershed Management & Operations Management 2000

June 20-24, 2000
Colorado State University
Fort Collins, Colorado

Available from:

Hydrologic Engineering Center
609 Second Street
Davis, Ca 95616

Via Internet at:
www.hec.usace.army.mil

Some History and Hydrology of the Panama Canal

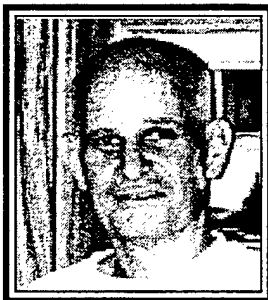
**Arthur F. Pabst
US Army, Corps of Engineers
Hydrologic Engineering Center
Davis, California**

I - Introduction

The Hydrologic Engineering Center (HEC) participated in the development of models for evaluating current and future alternatives for sustaining and improving water management of the Panama Canal. This paper presents some history regarding the construction of the Panama Canal and a general overview of the hydrology of the canal watershed.

II - Historical Overview

The United States officially took over the task of canal construction on May 4, 1904. Approximately ten years later, on August 15, 1914, the steamer SS Ancon made the first official canal transit. Much has been written about the events that led up to the United States taking up the gauntlet, after the French attempt which cost dearly in economic and human suffering. The French exerted intense political effort within the US in the hope of recovering some of the financial loss they suffered. Significant conflicts existed between several US political factions regarding where an Atlantic-Pacific canal should be built.



Gaspar Alvarado

Dedicated in memory of

Gaspar Alvarado

March 7, 1939 to July 20, 1999

Hydrologic Engineer
Panama Canal Commission

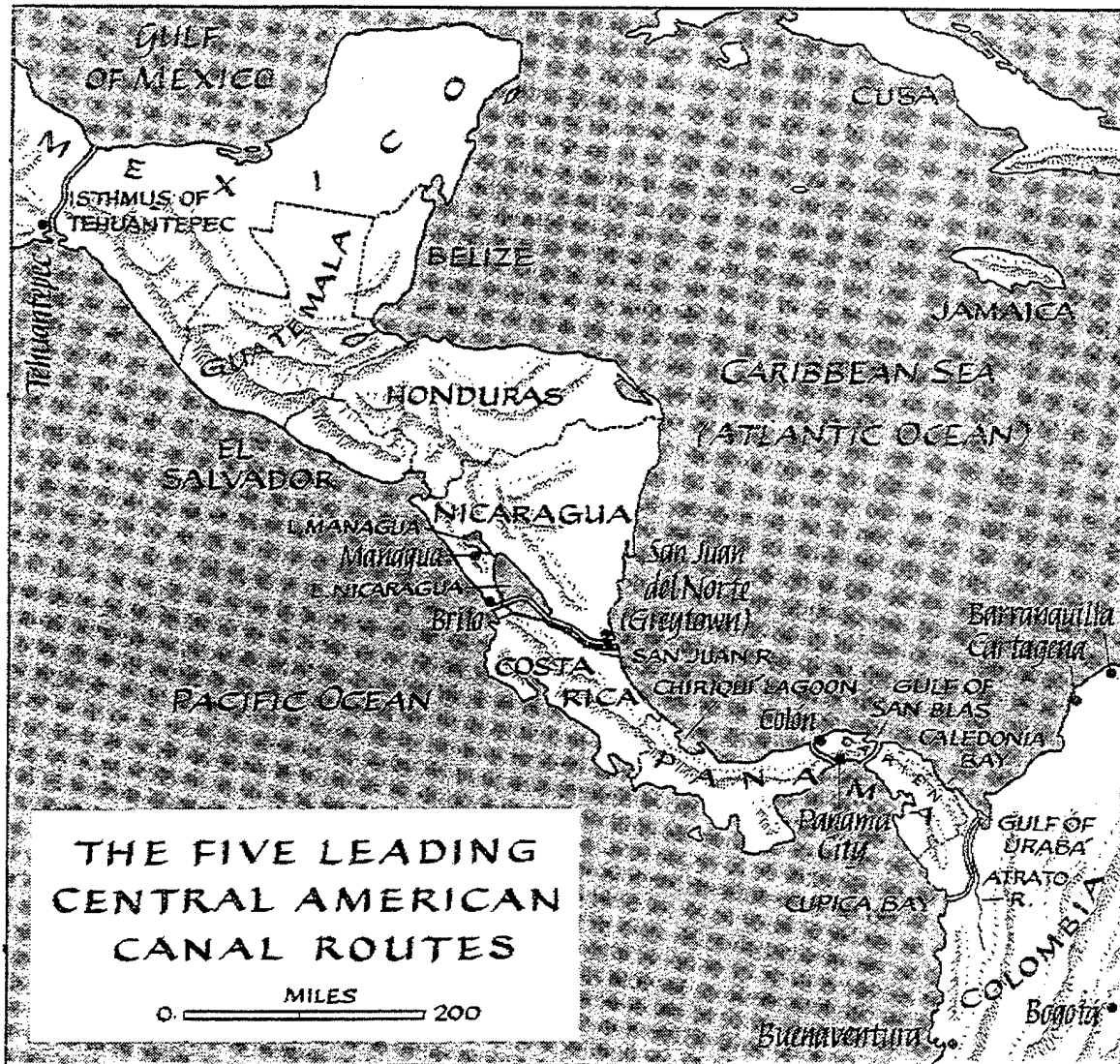


Figure 1 Alternative canal sites. (From Ref. 1)

Figure 1 shows five of the proposed routes that were under consideration. The strongest alternative to the actually constructed route was the one in Nicaragua. Politics at the time played a significant role in these decisions as compared to engineering considerations. There were several interests that sought to influence which of the routes should be chosen, with the French hoping to reduce their financial losses by selling their canal rights in Panama to the US.

Figures 2 and 3 show items that were used by the advocates of the Panama route to counter those favoring the Nicaragua route. The flat arch located in Panama City (shown in Figure 2) was offered as proof that Panama was an area of stable ground conditions. As the photo shows, this flat arch still exists today. The Nicaraguan postage stamp (shown in Figure 3) was sent to each US senator to carry the message that Nicaragua was an area of unstable ground conditions.

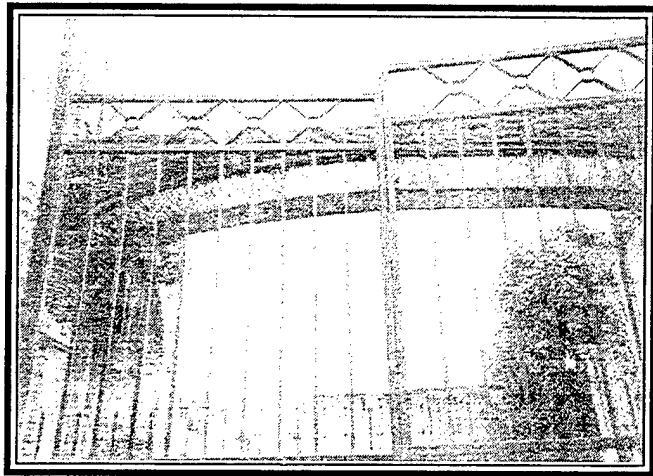


Figure 2 "Flat arch" in Panama City, Nov 1998.

In the time preceding the route decision, Panama was a territory of Columbia. The choice of Panama as a route naturally required negotiation with Columbia. These negotiations did not go well, eventually leading to the local Panama politicians triggering a revolt for their own independence from Columbia. The US stood to benefit greatly by such a change and under the guise of protecting US interests in the Panama Railroad, US Naval vessels appeared on the Atlantic and Pacific coasts of Panama effectively blocking Columbia from dealing with the rebellion. In the end the French interests were paid \$40,000,000 for the canal works, the new Panama government was paid \$10,000,000 and the US effort commenced. Later, in 1921, Columbia was paid \$25,000,000 by the US for the loss of Panama.



Figure 3 Nicaraguan stamp showing a volcano. (From Ref 1)

III - Engineering Considerations

The French had considered several alternative canal designs in their initial efforts. The sea level design had won out based on the successful French built Suez Canal. With greater engineering information to go on, the US abandoned the French design and proceeded with a design based on a large lake at elevation 85 with three locks at the Atlantic (North) side at Gatun and a one and two lock combination on the Pacific (South) side. The sea level design suffered

greatly from the larger volume of excavation required and from flooding that would have occurred along the Chagres River. The Chagres River was subject to frequent flooding that would have endangered the canal and impacted navigation traffic. By constructing a dam near the mouth of the Chagres River, the combined effect of reducing excavation and mitigating flood impacts was achieved at the cost of constructing lock structures.

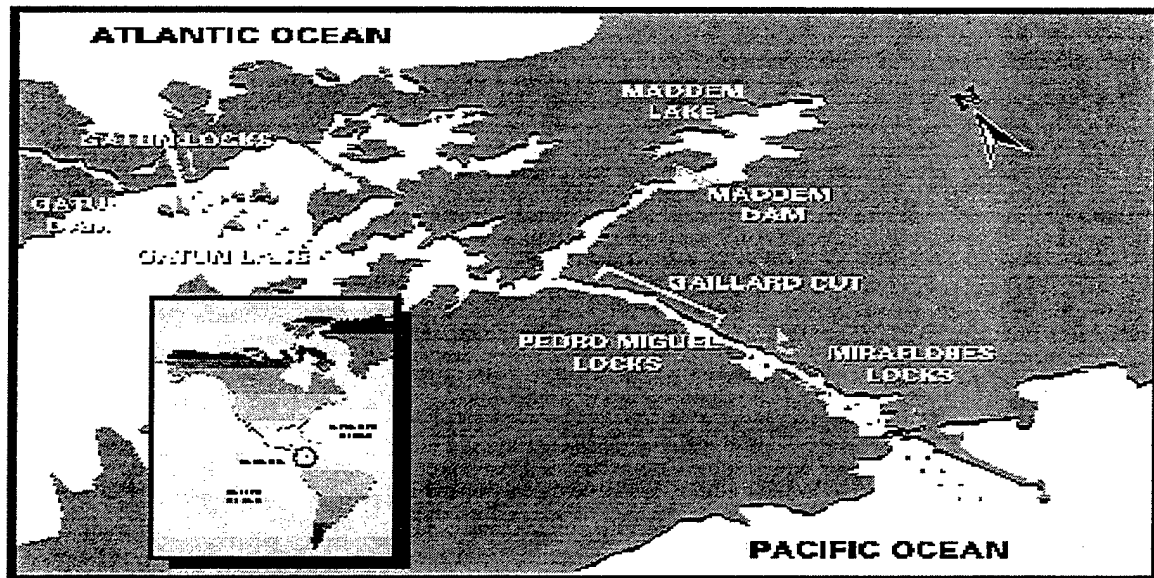


Figure 4 Panama Canal Features, Gatun and Madden Lakes.

Figure 4 shows the location of the lakes and lock structures. Dual lock chambers were constructed at all locations permitting bidirectional transits and allowing lock maintenance to be performed with only reduced traffic capacity. All lock chambers are 1000 feet in length and 110 feet in width. The locks are controlled by a well designed electro-mechanical control system (Figure 5) in place and still functional since 1914.

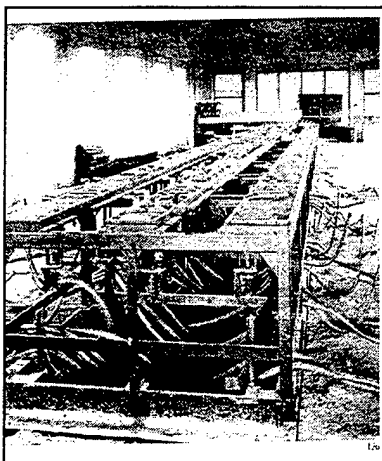


Figure 5 Lock control panel.
(From Ref 2)

Some of the lock gate systems (Figure 6) have been upgraded with hydraulic components; however, in some locks the same gear mechanisms that were designed in 1914 are currently being used to open and close the lock gates.

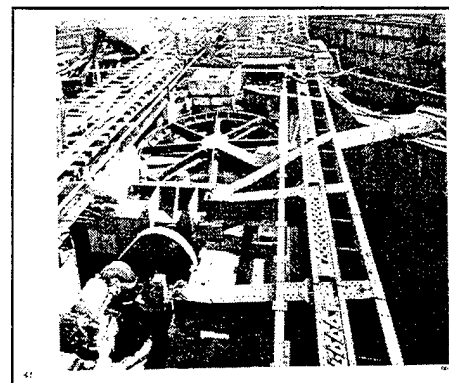


Figure 6 Gear gate mechanism 1914
(From Ref 2)

IV - Hydrology

The Panama Canal watershed is 1289 square miles drained by six rivers. The Chagres is the largest of the rivers and is the source for a major portion of the watershed runoff.

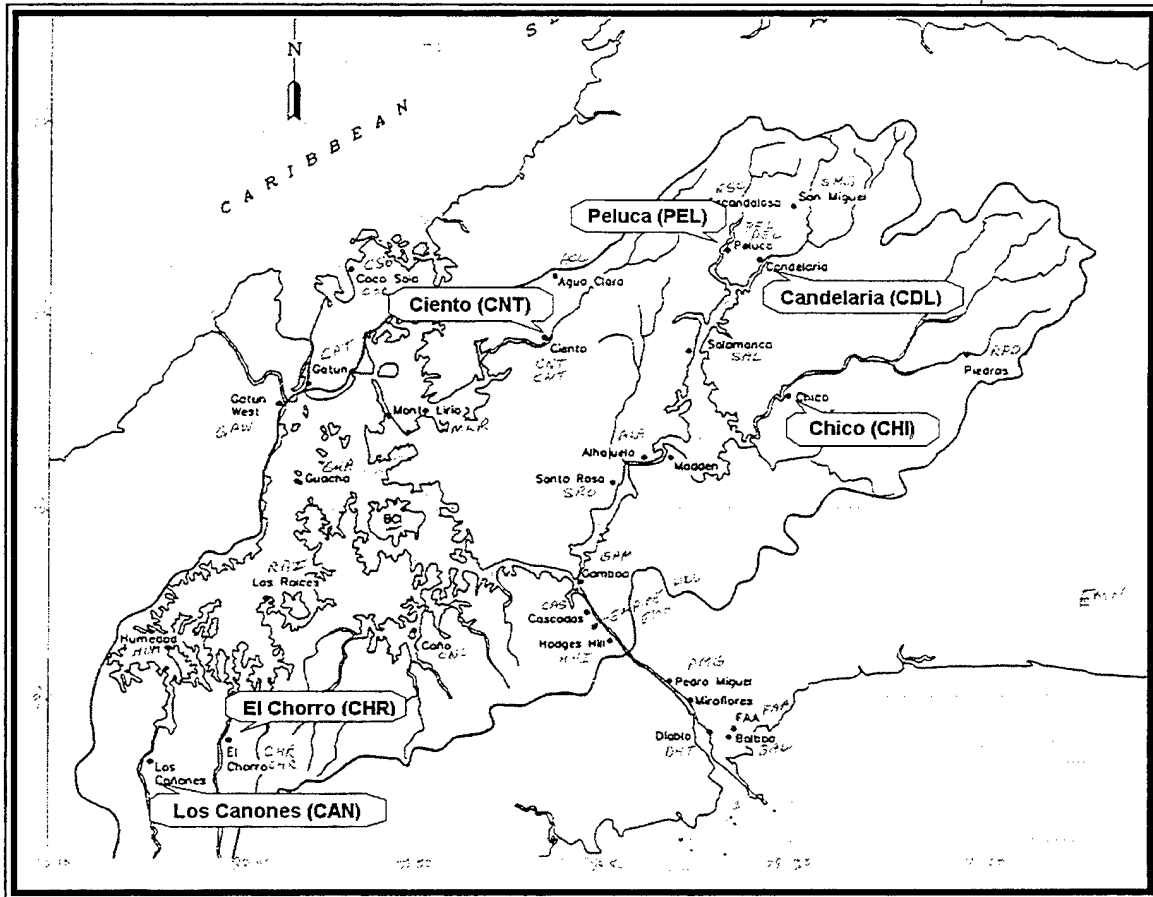


Figure 7 - Map showing stream gage locations.

Figure 7 shows the location of the major stream gages in the basin. Clockwise from the top the Gatun River is gaged at Ciento (CNT), the Boqueron at Peluca (PEL), the Pequeni at Candelaria (CDL), the Chagres at Chico (CHI), the Trinidad at El Chorro (CHR), and the Ciri Grande at Los Canones (CAN). The records at these long term stations provide excellent information for modeling runoff into the system. The Madden dam on the upper Chagres was completed in 1934 to provide water storage, flood control and hydropower. The Madden dam controls 396 square miles of tributary area. About 30 years of data are available for all these gages with longer records being available for some of the gages. Four meteorological stations record wind, humidity, radiation and related parameters.

A network of more than 30 precipitation gages and a weather radar station monitor rainfall events over the area. The locations of the precipitation gages are shown in Figure 8. The predominant storm direction is from the north. On the Atlantic coast, warm moist air from the Caribbean Sea crosses the isthmus moving southward. The mountains (400 to 900 feet high) along the northeast coast of the watershed cause uplift which contributes to the production of about 130 inches of annual precipitation in that area. Thirty miles south (at Balboa on the Pacific coast) the precipitation is about 60 inches, or only half as much.

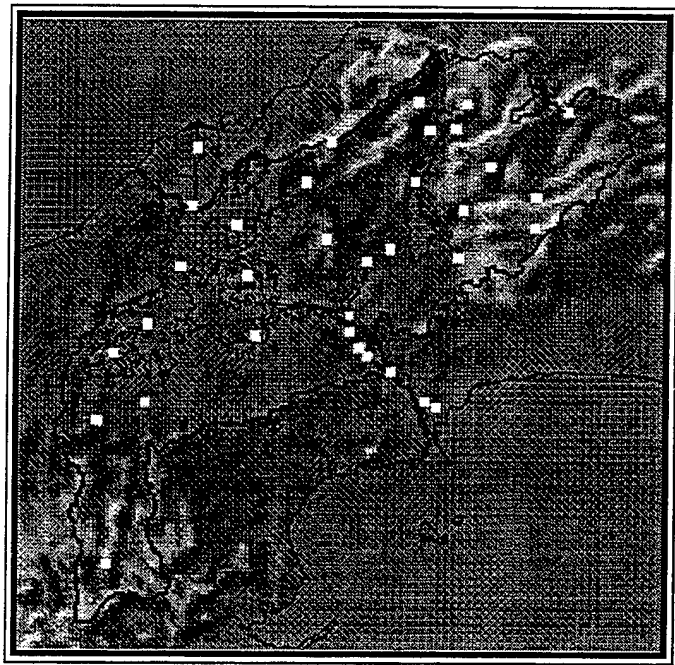


Figure 8 Network of Precipitation gages.

Figure 9 shows the key elements of the water budget in the Canal watershed. Madden Lake receives inflow from its contributing drainage area. Municipal water supply is withdrawn from the Madden Reservoir. All other outflows from Madden contribute to Gatun Lake. Madden attempts to pass all of its releases through its power turbines. Spillway discharges are necessary during high flow periods. The primary use of Gatun water is for lockages on the Atlantic and Pacific coasts. When excess water is present, discharges are made through turbines at Gatun Dam. Flows in excess of turbine capacity are passed over the Gatun spillway. Municipal water supply is also withdrawn from Gatun Lake.

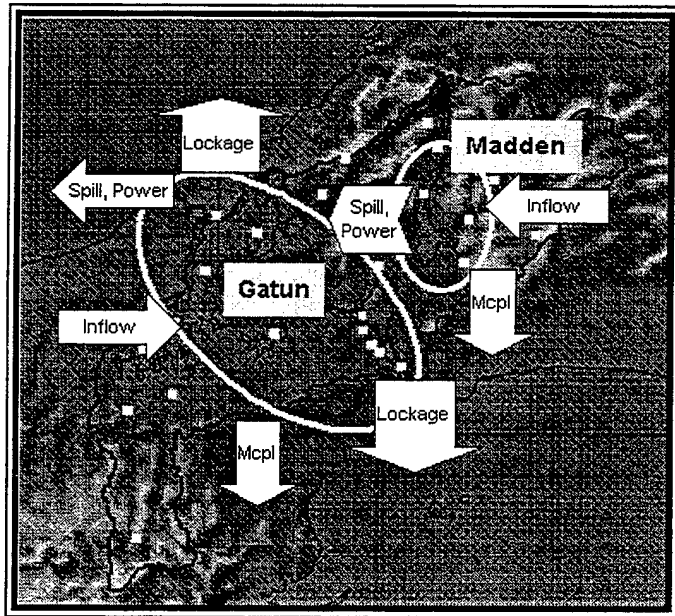


Figure 9 - Water budget for Panama Canal System.

On an annual basis, the Canal watershed receives about 101 inches of precipitation. Approximately 40 inches of this precipitation is lost from the perspective of water budget, going to infiltration, groundwater and plant use. Approximately 6 inches is estimated to evaporate from lake surfaces. Spill during high flows accounts for about 4 inches on an annual basis. Of the remaining 51 inches, 31 inches are used for lockages, 17 inches are used for hydropower, and 3 inches satisfy municipal water supply needs.

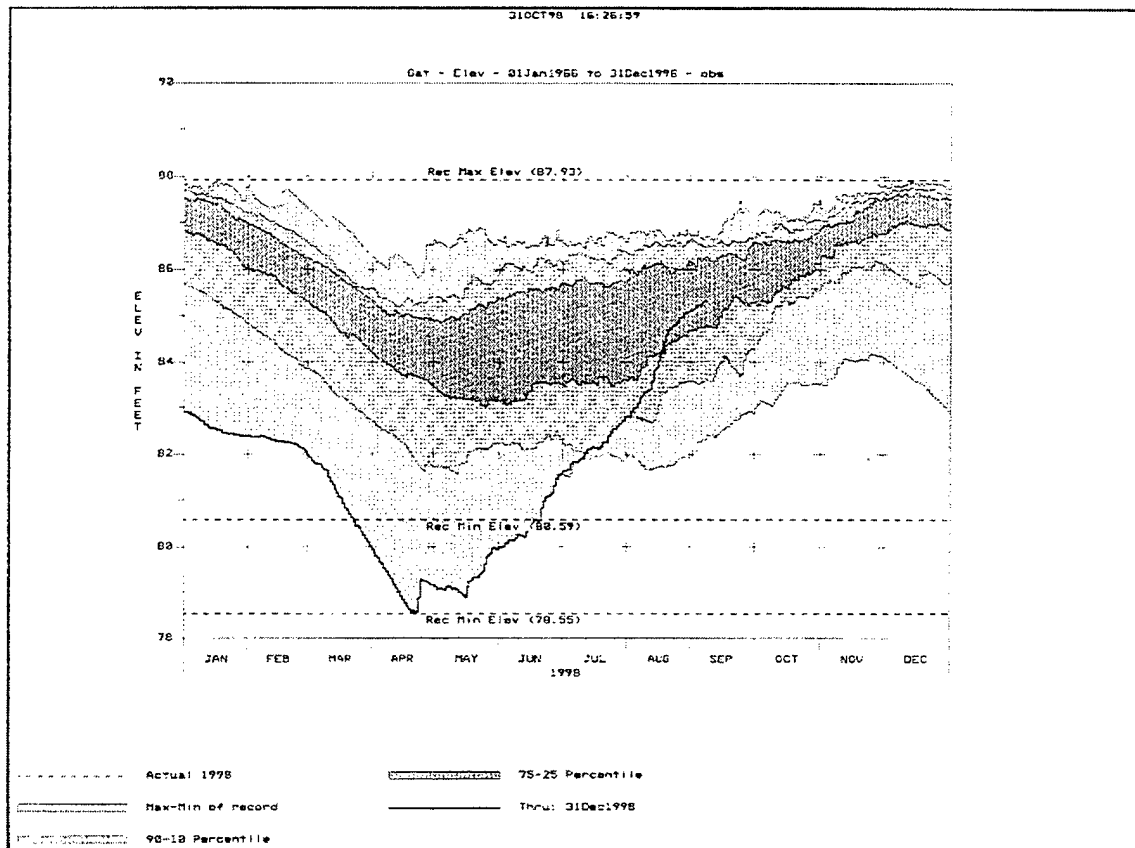


Figure 10 - Percentiles of Water Surface Elevations for Gatun Lake (1966 to 1998).

The nominal water surface elevation of Gatun Lake is 85 feet, with an average elevation of 85.70 feet. The maximum elevation of record is 87.93 feet (shown by the dotted line near the top of Figure 10) occurred in 1993. Of particular interest is the lowest elevation of record. Until 1998, the lowest elevation of record was 80.59 feet. In 1998, the level dropped to 78.55 (shown by the dotted line near the bottom of Figure 10), a full two feet lower than previously experienced since the canal was opened in 1914. Figure 10 shows percentiles of Gatun lake elevation on a daily basis for the period 1966 through 1998. The curves from highest to lowest are: the Maximum value, 90 , 75 , 25 , and 10 percentiles, and the Minimum value. The canal watershed system shows a remarkable resilience in its ability to recover from extreme conditions. The dark curve traces the daily elevations through August 1998, where it returned to the median level (after the record low in April).

V - Reservoir Modeling

In support of Panama Canal Authority (PCA) studies investigating canal capacity, the HEC developed an HEC-5 Reservoir simulation model of the existing canal system. The model included the two reservoirs, Gatun and Madden, reservoir operation rules, and a representation of the system water demands for lockage and municipal water supply. The HEC-5 model also included hydropower generation, spillway discharges, and lake evaporation. The model was verified using the derived lake inflows for the period of January 1980 through July 1998. The model was evaluated as to its ability to represent the behavior of the system under existing conditions. The verified existing condition model was then the basis for evaluating alternative system modifications. As alternatives are proposed, the model can be changed to evaluate the ability of the system to meet increased lockage demands, growth in municipal usage, and hydropower goals. Those alternatives that appear to be feasible can be simulated in detail at a daily operational time interval.

VI - Acknowledgments

In addition to the references cited below, a great deal of information was provided by PCA staff. Significant contributions of basic data, discussion on behavior of the canal system, and operating experience were provided by the following individuals of the PCA Met & Hyd Branch: Sigli Probst (Retired), Carlos Vargas, Jorge Espinosa, Modesto Echevers, Manuel Vilar, Mike Hart, and Maritza Chandeck. Assistance was also furnished by staff of the Canal Capacity Projects Office: Teodolinda Atencio, Jorge de la Guardia, Abelardo Bal, Agustin Arias, and John Gribar.

VII - References

1. *"The Path Between the Seas"* by David McCullough, A Touchstone Book - Simon & Schuster. 1977 Much of the historical material cited is based on this interesting and complete book on the building of the Panama Canal.
2. *"The Building of the Panama Canal in Historical Photographs"* By Ulrich Keller, Dover Publications, NY. 1983
3. *"The Panama Canal"* Informational brochure by Panama Canal Commission. 1997
4. *"www.pancanal.com"* Panama Canal Authority - Web Site. 2000
5. *"Panama Canal Reservoir System"* Project Report, Hydrologic Engineering Center, Davis, CA 1999
6. *"Panama Canal Capacity Study - Flow Data Processing"* Project Report, Hydrologic Engineering Center, Davis, CA 1999

REPORT DOCUMENTATION PAGE			Form Approved OMB No. 0704-0188	
Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188), Washington, DC 20503.				
1. AGENCY USE ONLY (Leave blank)	2. REPORT DATE June 2000	3. REPORT TYPE AND DATES COVERED Technical Paper (TP)		
4. TITLE AND SUBTITLE Some History and Hydrology of the Panama Canal			5. FUNDING NUMBERS	
6. AUTHOR(S) Arthur F. Pabst				
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) US ARMY CORPS OF ENGINEERS HYDROLOGIC ENGINEERING CENTER (HEC) 609 Second Street Davis, CA 95616-4687			8. PERFORMING ORGANIZATION REPORT NUMBER TP-159	
9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)			10. SPONSORING / MONITORING AGENCY REPORT NUMBER	
11. SUPPLEMENTARY NOTES				
12a. DISTRIBUTION / AVAILABILITY STATEMENT Unlimited. Approved for Public Release.			12b. DISTRIBUTION CODE	
13. ABSTRACT (Maximum 200 words) At the request of the Panama Canal Commission (now Panama Canal Authority), the Hydrologic Engineering Center participated in the development of a model to simulate the existing operation of the Panama Canal System. This model was developed to be a basis for evaluating alternative water use scenarios. The model reflected the existing two lakes (Gatun Lake and Madden Lake), navigation lockage water demands, municipal water supply, hydropower, and flood spillway flows. This paper describes some of the history related to the construction of the Panama Canal, the lock and lake design that was implemented, and some of the water uses in the basin.				
14. SUBJECT TERMS Panama Canal, canal hydrology, canal reservoir operations, canal history.			15. NUMBER OF PAGES 8	
			16. PRICE CODE	
17. SECURITY CLASSIFICATION OF REPORT UNCLASSIFIED	18. SECURITY CLASSIFICATION OF THIS PAGE UNCLASSIFIED	19. SECURITY CLASSIFICATION OF ABSTRACT UNCLASSIFIED	20. LIMITATION OF ABSTRACT UNLIMITED	

TECHNICAL PAPER SERIES

- | | | | |
|-------|--|-------|---|
| TP-1 | Use of Interrelated Records to Simulate Streamflow | TP-38 | Water Quality Evaluation of Aquatic Systems |
| TP-2 | Optimization Techniques for Hydrologic Engineering | TP-39 | A Method for Analyzing Effects of Dam Failures in Design Studies |
| TP-3 | Methods of Determination of Safe Yield and Compensation Water from Storage Reservoirs | TP-40 | Storm Drainage and Urban Region Flood Control Planning |
| TP-4 | Functional Evaluation of a Water Resources System | TP-41 | HEC-5C, A Simulation Model for System Formulation and Evaluation |
| TP-5 | Streamflow Synthesis for Ungaged Rivers | TP-42 | Optimal Sizing of Urban Flood Control Systems |
| TP-6 | Simulation of Daily Streamflow | TP-43 | Hydrologic and Economic Simulation of Flood Control Aspects of Water Resources Systems |
| TP-7 | Pilot Study for Storage Requirements for Low Flow Augmentation | TP-44 | Sizing Flood Control Reservoir Systems by Systems Analysis |
| TP-8 | Worth of Streamflow Data for Project Design - A Pilot Study | TP-45 | Techniques for Real-Time Operation of Flood Control Reservoirs in the Merrimack River Basin |
| TP-9 | Economic Evaluation of Reservoir System Accomplishments | TP-46 | Spatial Data Analysis of Nonstructural Measures |
| TP-10 | Hydrologic Simulation in Water-Yield Analysis | TP-47 | Comprehensive Flood Plain Studies Using Spatial Data Management Techniques |
| TP-11 | Survey of Programs for Water Surface Profiles | TP-48 | Direct Runoff Hydrograph Parameters Versus Urbanization |
| TP-12 | Hypothetical Flood Computation for a Stream System | TP-49 | Experience of HEC in Disseminating Information on Hydrological Models |
| TP-13 | Maximum Utilization of Scarce Data in Hydrologic Design | TP-50 | Effects of Dam Removal: An Approach to Sedimentation |
| TP-14 | Techniques for Evaluating Long-Term Reservoir Yields | TP-51 | Design of Flood Control Improvements by Systems Analysis: A Case Study |
| TP-15 | Hydrostatistics - Principles of Application | TP-52 | Potential Use of Digital Computer Ground Water Models |
| TP-16 | A Hydrologic Water Resource System Modeling Techniques | TP-53 | Development of Generalized Free Surface Flow Models Using Finite Element Techniques |
| TP-17 | Hydrologic Engineering Techniques for Regional Water Resources Planning | TP-54 | Adjustment of Peak Discharge Rates for Urbanization |
| TP-18 | Estimating Monthly Streamflows Within a Region | TP-55 | The Development and Servicing of Spatial Data Management Techniques in the Corps of Engineers |
| TP-19 | Suspended Sediment Discharge in Streams | TP-56 | Experiences of the Hydrologic Engineering Center in Maintaining Widely Used Hydrologic and Water Resource Computer Models |
| TP-20 | Computer Determination of Flow Through Bridges | TP-57 | Flood Damage Assessments Using Spatial Data Management Techniques |
| TP-21 | An Approach to Reservoir Temperature Analysis | TP-58 | A Model for Evaluating Runoff-Quality in Metropolitan Master Planning |
| TP-22 | A Finite Difference Method for Analyzing Liquid Flow in Variably Saturated Porous Media | TP-59 | Testing of Several Runoff Models on an Urban Watershed |
| TP-23 | Uses of Simulation in River Basin Planning | TP-60 | Operational Simulation of a Reservoir System with Pumped Storage |
| TP-24 | Hydroelectric Power Analysis in Reservoir Systems | TP-61 | Technical Factors in Small Hydropower Planning |
| TP-25 | Status of Water Resource Systems Analysis | TP-62 | Flood Hydrograph and Peak Flow Frequency Analysis |
| TP-26 | System Relationships for Panama Canal Water Supply | TP-63 | HEC Contribution to Reservoir System Operation |
| TP-27 | System Analysis of the Panama Canal Water Supply | TP-64 | Determining Peak-Discharge Frequencies in an Urbanizing Watershed: A Case Study |
| TP-28 | Digital Simulation of an Existing Water Resources System | TP-65 | Feasibility Analysis in Small Hydropower Planning |
| TP-29 | Computer Applications in Continuing Education | TP-66 | Reservoir Storage Determination by Computer Simulation of Flood Control and Conservation Systems |
| TP-30 | Drought Severity and Water Supply Dependability | TP-67 | Hydrologic Land Use Classification Using LANDSAT |
| TP-31 | Development of System Operation Rules for an Existing System by Simulation | TP-68 | Interactive Nonstructural Flood-Control Planning |
| TP-32 | Alternative Approaches to Water Resource System Simulation | TP-69 | Critical Water Surface by Minimum Specific Energy Using the Parabolic Method |
| TP-33 | System Simulation for Integrated Use of Hydroelectric and Thermal Power Generation | TP-70 | Corps of Engineers Experience with Automatic Calibration of a Precipitation-Runoff Model |
| TP-34 | Optimizing Flood Control Allocation for a Multipurpose Reservoir | TP-71 | Determination of Land Use from Satellite Imagery for Input to Hydrologic Models |
| TP-35 | Computer Models for Rainfall-Runoff and River Hydraulic Analysis | TP-72 | Application of the Finite Element Method to Vertically Stratified Hydrodynamic Flow and Water Quality |
| TP-36 | Evaluation of Drought Effects at Lake Atitlan | | |
| TP-37 | Downstream Effects of the Levee Overtopping at Wilkes-Barre, PA, During Tropical Storm Agnes | | |

- TP-73 Flood Mitigation Planning Using HEC-SAM
- TP-74 Hydrographs by Single Linear Reservoir Model
- TP-75 HEC Activities in Reservoir Analysis
- TP-76 Institutional Support of Water Resource Models
- TP-77 Investigation of Soil Conservation Service Urban Hydrology Techniques
- TP-78 Potential for Increasing the Output of Existing Hydroelectric Plants
- TP-79 Potential Energy and Capacity Gains from Flood Control Storage Reallocation at Existing U. S. Hydropower Reservoirs
- TP-80 Use of Non-Sequential Techniques in the Analysis of Power Potential at Storage Projects
- TP-81 Data Management Systems for Water Resources Planning
- TP-82 The New HEC-1 Flood Hydrograph Package
- TP-83 River and Reservoir Systems Water Quality Modeling Capability
- TP-84 Generalized Real-Time Flood Control System Model
- TP-85 Operation Policy Analysis: Sam Rayburn Reservoir
- TP-86 Training the Practitioner: The Hydrologic Engineering Center Program
- TP-87 Documentation Needs for Water Resources Models
- TP-88 Reservoir System Regulation for Water Quality Control
- TP-89 A Software System to Aid in Making Real-Time Water Control Decisions
- TP-90 Calibration, Verification and Application of a Two-Dimensional Flow Model
- TP-91 HEC Software Development and Support
- TP-92 Hydrologic Engineering Center Planning Models
- TP-93 Flood Routing Through a Flat, Complex Flood Plain Using a One-Dimensional Unsteady Flow Computer Program
- TP-94 Dredged-Material Disposal Management Model
- TP-95 Infiltration and Soil Moisture Redistribution in HEC-1
- TP-96 The Hydrologic Engineering Center Experience in Nonstructural Planning
- TP-97 Prediction of the Effects of a Flood Control Project on a Meandering Stream
- TP-98 Evolution in Computer Programs Causes Evolution in Training Needs: The Hydrologic Engineering Center Experience
- TP-99 Reservoir System Analysis for Water Quality
- TP-100 Probable Maximum Flood Estimation - Eastern United States
- TP-101 Use of Computer Program HEC-5 for Water Supply Analysis
- TP-102 Role of Calibration in the Application of HEC-6
- TP-103 Engineering and Economic Considerations in Formulating
- TP-104 Modeling Water Resources Systems for Water Quality
- TP-105 Use of a Two-Dimensional Flow Model to Quantify Aquatic Habitat
- TP-106 Flood-Runoff Forecasting with HEC-1F
- TP-107 Dredged-Material Disposal System Capacity Expansion
- TP-108 Role of Small Computers in Two-Dimensional Flow Modeling
- TP-109 One-Dimensional Model For Mud Flows
- TP-110 Subdivision Froude Number
- TP-111 HEC-5Q: System Water Quality Modeling
- TP-112 New Developments in HEC Programs for Flood Control
- TP-113 Modeling and Managing Water Resource Systems for Water Quality
- TP-114 Accuracy of Computed Water Surface Profiles - Executive Summary
- TP-115 Application of Spatial-Data Management Techniques in Corps Planning
- TP-116 The HEC's Activities in Watershed Modeling
- TP-117 HEC-1 and HEC-2 Applications on the MicroComputer
- TP-118 Real-Time Snow Simulation Model for the Monongahela River Basin
- TP-119 Multi-Purpose, Multi-Reservoir Simulation on a PC
- TP-120 Technology Transfer of Corps' Hydrologic Models
- TP-121 Development, Calibration and Application of Runoff Forecasting Models for the Allegheny River Basin
- TP-122 The Estimation of Rainfall for Flood Forecasting Using Radar and Rain Gage Data
- TP-123 Developing and Managing a Comprehensive Reservoir Analysis Model
- TP-124 Review of the U.S. Army Corps of Engineering Involvement With Alluvial Fan Flooding Problems
- TP-125 An Integrated Software Package for Flood Damage Analysis
- TP-126 The Value and Depreciation of Existing Facilities: The Case of Reservoirs
- TP-127 Floodplain-Management Plan Enumeration
- TP-128 Two-Dimensional Floodplain Modeling
- TP-129 Status and New Capabilities of Computer Program HEC-6: "Scour and Deposition in Rivers and Reservoirs"
- TP-130 Estimating Sediment Delivery and Yield on Alluvial Fans
- TP-131 Hydrologic Aspects of Flood Warning - Preparedness Programs
- TP-132 Twenty-five Years of Developing, Distributing, and Supporting Hydrologic Engineering Computer Programs
- TP-133 Predicting Deposition Patterns in Small Basins
- TP-134 Annual Extreme Lake Elevations by Total Probability Theorem
- TP-135 A Muskingum-Cunge Channel Flow Routing Method for Drainage Networks
- TP-136 Prescriptive Reservoir System Analysis Model - Missouri River System Application
- TP-137 A Generalized Simulation Model for Reservoir System Analysis
- TP-138 The HEC NexGen Software Development Project
- TP-139 Issues for Applications Developers
- TP-140 HEC-2 Water Surface Profiles Program
- TP-141 HEC Models for Urban Hydrologic Analysis
- TP-142 Systems Analysis Applications at the Hydrologic Engineering Center
- TP-143 Runoff Prediction Uncertainty for Ungauged Agricultural Watersheds
- TP-144 Review of GIS Applications in Hydrologic Modeling

- TP-145 Application of Rainfall-Runoff Simulation for Flood Forecasting
- TP-146 Application of the HEC Prescriptive Reservoir Model in the Columbia River System
- TP-147 HEC River Analysis System (HEC-RAS)
- TP-148 HEC-6: Reservoir Sediment Control Applications
- TP-149 The Hydrologic Modeling System (HEC-HMS): Design and Development Issues
- TP-150 The HEC Hydrologic Modeling System
- TP-151 Bridge Hydraulic Analysis with HEC-RAS
- TP-152 Use of Land Surface Erosion Techniques with Stream Channel Sediment Models
- TP-153 Risk-based Analysis for Corps Flood Project Studies - a Status Report
- TP-154 Modeling Water-Resource Systems for Water Quality Management
- TP-155 Runoff Simulation Using Radar Rainfall Data
- TP-156 Status of HEC Next Generation Software Development
- TP-157 Unsteady Flow Model for Forecasting Missouri and Mississippi Rivers
- TP-158 Corps Water Management System (CWSM)
- TP-159 Some History and Hydrology of the Panama Canal